# “Measuring long-run security price performance: a review”


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# Measuring long-run security price performance: a review


## Abstract

Although long-term event studies have seen many advances over the years, the interpretation of long-run results is still problematic. In the present paper, the authors review a large number of long-run event studies and find that the analysis of long-run abnormal performance is perfidious. In addition, an empirical example is given to compare several measures of long run stock price performance. The empirical analysis shows that a recently proposed calendar time portfolio method has better performance than the conventional approaches. However, despite these positive developments in long-run event study methodology, the power and specification issues still remain unsolved and further filtering of the existing approaches is thus required for solving such issues.


**Keywords:** long-run event studies, abnormal returns, specification issue, power issue.
**JEL Classification:** C1, G1.

## Introduction

Since the seminal paper of Fama, Fisher, Jensen and Roll (1969) in the late 1960s, the event study methodology has become an important tool of testing market efficiency. Such methodology is employed for the purpose of analyzing the stock market responses to certain corporate events such as mergers and acquisitions, IPOs, stock split etc. That is, event studies are empirical procedures for investigating the effect of an event on stock returns. However, typical events are of two types: Firm-specific events and Economy-wide events. Firm-specific events usually indicate a change in the company policy. Examples of such events include earnings, investment, mergers and acquisitions, issues of new debt or equity, stock splits, etc. announcements. Economy-wide events, on the other hand, are used to assess the impact of a particular event on relevant securities. This type of events includes inflation, interest rate, consumer confidence, trade deficient, etc. announcements.

In event studies, the data to be analyzed can be daily, weekly, monthly, or annually. While the earlier studies in financial economics such as Brown and Warner (1980, 1985), Corrado (1989), Campbell and Wasley (1993), Kolari and Pynnönen (2011) etc. focus on the characteristics of abnormal returns measured on a particular day or, at the most cumulated over several months, a large number of recent studies investigate the stock price performance of firms for periods of one to five years following significant corporate events. The extensive literature of long-horizon event studies includes Barber and Lyon (1997), Kothari and Warner (1997), Fama (1998), Lyon, Barber, and Tsai (1999), Mitchell and Stafford (2000), Boehme and Sorescu (2002) and so on.

Although long-run event studies have a long history, serious limitations still exist. Kothari and Warner (1997), for example, document that while short-horizon methods are quite reliable, inferences from long-horizon tests require extreme caution. Lyon et al. (1999) also conclude that the analysis of long-run abnormal performance is treacherous. Short-run event studies, on the other hand, are relatively stable and free of limitations. For instance, Fama (1991) reports that short-horizon tests represent the cleanest evidence we have on efficiency, but the interpretation of long-horizon results is problematic. Further filtering of the existing long-run methodologies is thus required.

However, the buy-and-hold abnormal return (BHAR) methodology and the calendar time portfolio (CTP) approach are the two widely employed methods for investigating long-term stock returns following major corporate events. The BHAR refers to the difference between the long-run holding period return of a sample firm and that of some benchmark asset. The CTP approach, on the other hand, is based on the mean abnormal time series returns to monthly portfolios of event firms. Unfortunately, each of these methods has a number of potential pitfalls. In this paper, we make a modest attempt to discuss these limitations and then we give an empirical example to compare the performance of the existing long-run event study approaches. In order to serve the latter purpose, we use the data from three major European stock markets such as Germany, France and Italy. We perform simulations to reach our goal. Our empirical analysis suggests that the standardized calendar time approach, which is a recently developed calendar time portfolio method, shows better performances than other conventional methods.

The rest of the paper is structured as follows. The next section outlines the existing literature of long-run event studies. Measures of long-run stock price performance are discussed in Section 2. Section 3 presents empirical example. The final section concludes the study.

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## 1. Literature review

While short-run event study methods are relatively straightforward and reliable (Fama, 1991), the proper methodology for measuring long-run abnormal stock returns is still much debated in the literature. Financial economists are always in search of the appropriate measure of long-run abnormal stock returns and the appropriate statistical methodology for testing the significance of any measured abnormal performance. Kothari and Warner (2007), for instance, argue that the question of which model of expected returns is correct remains an unresolved issue. Fama (1998) also concludes that not a single model for expected returns can present a complete description of the systematic patterns in average returns.

However, beginning with Ritter (1991), the most popular estimator of long-run abnormal performance is the mean buy-and-hold abnormal return (BHAR). Mitchell and Stafford (2000) define BHARs as the average multiyear return from a strategy of investing in all firms that complete an event and selling at the end of a prespecified holding period versus a comparable strategy using otherwise similar nonevent firms. An appealing feature of using BHAR is that buy-and-hold returns better resemble investors actual investment experience than periodic (monthly) re-balancing entailed in other approaches to measuring risk-adjusted performance.

Fama (1998), however, argues against the BHAR methodology because of the statistical problems associated with the use of the BHAR and the associated test statistics. In addition, any methodology ignoring the cross-sectional dependence of event-firm abnormal returns that do overlap in calendar time is likely to produce overstated test statistics. Eckbo et al. (2000) also argue against the application of buy-and-hold abnormal return method. They document that the BHAR methodology is not a feasible portfolio strategy because the total number of stocks is not known in advance. Later, Jegadeesh and Karceski (2009) criticize the BHAR approach arguing that it assumes the cross-sectional independence of abnormal returns, while such assumption is violated in nonrandom samples, where the event firm returns are positively correlated.

Barber and Lyon (1997) and Lyon et al. (1999) identify new listing, re-balancing, and skewness biases with inference in long-run event studies using the BHAR. They use simulations to investigate the impact of these biases on inference when BHAR is exercised to measure the abnormal performance and standard tests are applied. However, in case of using a reference portfolio to capture expected return, the new listing and rebalancing biases can be addressed in a relatively simple way by careful construction of the reference portfolio (see Lyon et al., 1999).

Unfortunately, the use of a reference portfolio to capture the expected return gives rise to the skewness bias. This bias arises due to the fact that the long-run return of a portfolio is compared with the long-run return of an individual asset. The long-run return of an individual security is highly skewed; whereas the long-run return for a reference portfolio (due to diversification) is not. Consequently, the BHAR, the difference between these returns, is also skewed. Barber and Lyon (1997) report that since BHAR is positively skewed, its use causes the standard tests to have the wrong size and causes the power of the test to be asymmetric; rejection rates are far higher when induced abnormal returns are negative than when they are positive.

To avoid the skewness bias, a control firm rather than a reference portfolio can be used as the long-run return benchmark. BHAR is then measured as the difference between the long-run holding-period returns of the event firm's equity and that of a control firm. Although the distribution of each asset's holding-period return is highly skewed, the distribution of their difference is not. As a result, standard statistical tests based on the control firm approach have the right size in random samples.

However, standard tests based on the control firm approach are not as powerful as those based on the reference portfolio approach. Lyon et al. (1999), for instance, argue that the use of a control firm is a noisier way to control for expected returns than is the use of a reference portfolio and this added noise reduces the power of the test. The variance of the difference between the returns on two individual assets is generally much higher than the variance of the difference between the return of an asset and that of a portfolio, even when the control firm is chosen carefully. Powerful tests thus require very large samples when control firm approach is applied.

To deal with the power and specification issues, Lyon et al. (1999) discuss two modes to modify the reference portfolio approach for fixing the associated size problem. The first of these two ways refers to the use of *p*-values generated from the empirical distribution of long-run abnormal returns, while the other suggests the use of skewness-adjusted *t*-statistics. Such methods, combined with careful construction of reference portfolios to remove the rebalancing and new listing biases, solve the size problem in random samples. However, Lyon, Barber, and Tsai observe that these corrections do not produce well-specified tests in many of the non-random samples considered in their study. In non-random samples the use of a standard

reference portfolio approach often fails to match the expected return of the event firm with the expected return of the reference portfolio resulting in a misspecified test. Furthermore, when the return on a diversified portfolio is employed to capture expected returns, there is no offset of any contemporaneous correlation of idiosyncratic returns that may exist across firms. This problem is likely to be heightened when the events get highly clustered in time. Fama (1998) strongly recommends the use of CTP methodology on the grounds that monthly returns are less susceptible to the bad model problem as they are less skewed and by forming monthly calendar time portfolios, all cross-correlations of event-firm abnormal returns are automatically accounted for in the portfolio variance. Fama also documents that the distribution of this estimator is better approximated by the normal distribution, allowing for classical statistical inference. Mitchell and Stafford (2000), like Fama (1998), also prefer the CTP approach to BHAR methodology as the latter assumes independence of multi-year event firm abnormal returns.

While many recent studies strongly advocate the CTP approach, it has a number of potential pitfalls. Loughran and Ritter (2000), for example, criticize the use of calendar time approach arguing that it gives equal weight to each month, regardless of whether the month has heavy or light event activities. They conclude that the calendar time portfolio regressions have low power to identify the abnormal performance because it averages over months of 'hot' and 'cold' event activity. Lyon et al. (1999), however, claim that the CTP approach is misspecified in nonrandom samples, while the BHAR approach is relatively robust.

The bottom line is that despite these positive developments in long-run event study methodology, the power and specification issues still remain unsolved and further refinement of the existing methods is required for solving these issues. Kothari and Warner (2007), for instance, conclude that whether calendar time, BHAR methods or some combination can best address long-horizon issues remains an open question.

## 2. Long-run event study approaches

**2.1. Buy-and-hold abnormal return (BHAR).** An *H*-month BHAR for event firm *i* is defined as:

$$BHAR_{iH} = \prod_{t=1}^{H}(1+R_{it}) - \prod_{t=1}^{H}(1+R_{Bt}), \quad (1)$$

where $R_{it}$ denotes the return on event firm *i* at time *t* and $R_{Bt}$ indicates the return on either a reference portfolio or a control firm.

To test the null hypothesis that the mean buy-and-hold return equals zero, the conventional *t*-statistic is given by:

$$t_{BHAR} = \frac{\overline{BHAR}}{\sigma(BHAR_H)/\sqrt{n}},$$

where $\overline{BHAR}_H$ implies the sample mean and $\sigma(BHAR_H)$ refers to the cross-sectional sample standard deviation of abnormal returns for the sample containing *n* firms.

However, the earlier studies such as Mitchell and Stafford (2000), Boehme and Sorescu (2002), Jegadeesh and Karceski (2009) report that the BHAR approach does not control well for the cross-sectional correlation among individual firms in nonrandom samples and thus yields misspecified *t*-statistics. Moreover, the test statistics based on BHARs also have this misspecification problem, since the distribution of BHARs is highly skewed. Though bootstrapping corrects for the skewness problem to some extent, it ignores the cross-sectional dependence of abnormal returns.

**2.2. Fama-French three-factor model.** For each calendar month *t*, we form portfolios consisting of all sample firms that have participated in the event within the last *H* months, where *H* equals 12, 36, or 60 in our study. For each calendar month, the portfolios are rebalanced, i.e., the firms that reach the end of their *H*-month period drop out and new firms that have just executed a transaction are added. We then calculate the portfolio mean monthly abnormal return $\alpha_p$ by regressing its excess return on the three Fama-French factors:

$$R_{pt} - R_{ft} = \alpha_p + \beta_p(R_{mt} - R_{ft}) + \\ + s_p SMB_t + h_p HML_t + e_{pt}, \quad (2)$$

where $R_{pt}$ is the equal or value-weighted return on portfolio *t*, $R_{ft}$ is the risk-free rate, $(R_{mt} - R_{ft})$ is the excess return of the market, *SMB* is the difference between the return on the portfolio of small stocks and big stocks, *HML* is the difference between the return on the portfolio of high and low book-to-market stocks, $\alpha_p$ measures the mean monthly abnormal return of the calendar time portfolio which is zero under the null hypothesis of no abnormal performance and $\beta_p$, $s_p$ and $h_p$ are sensitivities of the event portfolio to the three factors.

However, since the number of firms changes over the sample period, this may cause the error term to be heteroskedastic and hence the ordinary least squares estimate becomes inefficient. Fama (1998), therefore, suggests to apply the weighted least squares technique instead of ordinary least squares

to control for heteroskedasticity. In this study, we estimate regression (2) using weighted least squares (WLS) procedures. Monthly returns in the WLS model are weighted by $\sqrt{N_t}$, where $N_t$ stands for the number of event firms in month *t*.

**2.3. Adjusted Fama-French three-factor model.** Fama and French (1993) document that the traditional three-factor model is not able to completely explain the cross section of stock returns. However, Mitchell and Stafford (2000) and later Boehme and Sorescu (2002) refine this three-factor model to deal with the bad model problem. In this paper, we also try to modify the conventional Fama-French three-factor model to moderate the size and book-to-market ratio biases. Our adjusted three-factor model assumes the following form:

$$(R_{event} - R_{control})_{pt} = \alpha_p + \beta_p (R_{mt} - R_{ft}) + \\ + s_p SMB_t + h_p HML_t + e_{pt}, \quad (3)$$

where $(R_{event} - R_{control})_{pt}$ is the equal- or value-weighted monthly portfolio return between the simple returns of each event firm and its size-BM matched control firm. Moreover, for portfolio *t*, $(R_{event} - R_{control})_{pt}$ contains those firms whose event period includes the month *t*. In this adjusted model, $\alpha_p$ is a measure of long-term abnormal performance which is zero under the null hypothesis that no abnormal performance exists. Now, to test this null hypothesis, the *t*-statistic is given as:

$$t = \frac{\hat{\alpha}_p}{s(\hat{\alpha}_p)},$$

where $\hat{\alpha}_p$ is an estimator of $\alpha_p$, and $s(\hat{\alpha}_p)$ is the corresponding standard error of $\hat{\alpha}_p$. Dutta (2014), however, argues that the adjusted three-factor model lacks power.

**2.4. Mean monthly calendar time abnormal returns (MMCTAR).** The calculation of mean monthly calendar time abnormal return (MMCTAR) is the following:

$$MMCTAR = \frac{1}{T}\sum_{t=1}^{T} CTAR_t, \quad (4)$$

where

$$CTAR_t = R_{pt} - E(R_{pt}). \quad (5)$$

Within this framework, $R_{pt}$ is the monthly return on the portfolio of event firms, $E(R_{pt})$ is the expected return on the event portfolio which is proxied by the raw return on either a reference portfolio or a control firm and *T* is the total number of months in the sample period. To test the null hypothesis of no abnormal returns, the *t*-statistic of MMCTAR is obtained by using the intertemporal standard deviation of the monthly CTARs defined in equation (5).

**2.5. Standardized calendar time approach (SCTA).** Forming the monthly portfolios in the standardized calendar time approach involves two steps (Dutta, 2014a). The first step involves the calculation of standardized abnormal returns for each of the sample firms. In doing so, the abnormal returns for firm *i* are computed as $\varepsilon_{it} = r_{it} - E(r_{it})$; $t = 1, ..., H$, where $r_{it}$ denotes the log return on event firm *i* in the calendar month *t* and $E(r_{it})$ is the expected return which is proxied by size/book-to-market reference portfolios and size/book-to-market matched control firm and *H* is the holding period which equals 12, 36 or 60 months. The next task is to estimate the event-portfolio residual variances using the *H*-month residuals computed as monthly differences of *i*-th event firm returns and control firm returns. Dividing $\varepsilon_{it}$ by the estimate of its standard deviation yields the corresponding standardized abnormal return, say, $z_{it}$, for event firm *i* in month *t*. Now let $N_t$ refer to the number of event firms in the calendar month *t*. We then calculate the calendar time abnormal return for portfolio *t* as:

$$CTAR_t = \sum_{i=1}^{N_t} x_{it} z_{it}, \quad (6)$$

where the weight $x_{it}$ equals $\frac{1}{N_t}$ when the abnormal returns are equally-weighted and $\frac{MV_{it}}{\sum MV_{it}}$ when the abnormal returns are value-weighted by size.

Following the work of Dutta, each of the monthly CTARs is weighted by $1\Big/\sqrt{(\sum_{i=1}^{N_t} x_{it}^2)}$. For instance, when the abnormal returns are equally weighted i.e., when $x_{it} = \frac{1}{N_t}$, then $1\Big/\sqrt{(\sum_{i=1}^{N_t} x_{it}^2)} = \sqrt{N_t}$. This weighting scheme is lucrative as it gives more loadings to periods of heavy event activity than the periods of low event activity. Now the grand mean monthly abnormal return, denoted by $\overline{CTAR}$, is calculated as:

$$\overline{CTAR} = \frac{1}{T}\sum_{1}^{T} CTAR_t. \quad (7)$$

While finding $\overline{CTAR}$, it might be the case that a number of portfolios do not contain any event firm. In such situations, those months are dropped from the analysis. To test the null hypothesis of no abnormal performance, the *t*-statistic of $\overline{CTAR}$ is computed by using the intertemporal standard

deviation of the monthly CTARs defined in equation (6). Dutta (2014b), however, shows that although SCTA documents better power and specification than the existing approaches, further refinement is still needed to improve the size and power in nonrandom samples.

Table 1 summarizes some previous simulation studies which compare the long-run event study methodologies reviewed in this paper. Inspecting the above table reveals that most of these studies have been conducted using the U.S. security market data. While few studies recommended the application of the buy-and-hold abnormal return method, the rest favored the calendar time portfolio approach for the analysis of long-run stock returns after significant corporate events.

Table 1. Summary of existing simulation studies

| Authors | Country | Sample period | Methods used | Recommended methods |
|---|---|---|---|---|
| Barber and Lyon (1997) | USA | July 1963 to December 1993 | BHAR, three-factor model | BHAR |
| Lyon, Barber and Tsai (1999) | USA | July 1973 to December 1994 | BHAR, three-factor model, MMCTAR | BHAR |
| Mitchell and Stafford (2000) | USA | January 1958 to December 1993 | BHAR, adjusted three-factor model, MMCTAR | Adjusted three-factor model, MMCTAR |
| Ang and Zhang (2004) | USA | January 1980 to December 1992 | BHAR, three-factor model | BHAR |
| Dutta (2014a) | USA | July 1978 to December 2007 | BHAR, MMCTAR, SCTA | SCTA |
| Dutta (2014b) | UK | July 1983 to December 2008 | BHAR, three-factor model, adjusted three-factor model, SCTA | SCTA |

## 3. Empirical example

This section gives an empirical example to discuss the size issue as well as the power issue of various methodologies reviewed in the present study. In doing so, we employ the security market data from three major European equity markets such as Germany, France and Italy. The results from Fama-French and adjusted Fama-French three factor models are not reported as the factors of these models are not available in these markets. We obtain stock prices, market value (MV) and book-to-market (BM) value data from DataStream. The sample period ranges from July 1978 to December 2007. We consider a size-BM-matched control firm to calculate the abnormal returns. Identifying such a control firm is a 2-step procedure. First, we identify all the firms with a market value of equity between 70% and 130% of the sample firm at the most recent end of June. Then from this set of firms, we choose the firm with BM closest to that of the sample firm as of the previous December. However, since the currencies of the financial markets differ from one to another, we construct the benchmarks for each market separately and then merge all the data sets.

However, for testing the specification of the *t*-statistics, we randomly select 1000 samples of 200 event months without replacement. For each of these 200 event months, we randomly draw one stock from the population of all stocks that are active in the database for that month. For a well-specified test statistic, $1000\alpha$ tests reject the null hypothesis. A test is conservative if fewer than $1000\alpha$ null hypotheses are rejected and is anticonservative if more than $1000\alpha$ null hypotheses are rejected. Based on this procedure, we test the specification of the *t*-statistic at 5% theoretical levels of significance. A well-specified null hypothesis rejects the null at the theoretical rejection level in favor of the alternative hypothesis of negative (positive) abnormal returns in $1000\alpha/2$ samples.

Table 2 presents the rejection rates in 1000 simulations with a random sample of 200 firms. The results show that all the *t*-statistics based on buy and hold abnormal returns are negatively biased suggesting that BHAR approach documents higher rejection rates in the lower tail. SCTA and MMCTAR method, however, produce reasonably well specified test statistics for different investment periods considered. For example, for a 3-year holding period, the rejection rates at 5% level of significance are 3.9% and 0.8% for BHAR method, 1.4% and 2.0% for SCTA and 3.2% and 2.8% for MMCTAR method. Although Table 2 shows the results for equally-weighted portfolios, our findings for value-weighted portfolios (not reported in the table) also conclude the same.

Table 3 displays the power of the alternative methods considered in our analysis. We report the percentages of 1000 random samples of 200 firms that reject the null hypothesis of no abnormal performances over a three-year investment period. In order to evaluate the power of a test, we introduce a constant level of abnormal return ranging from -20% to 20% at an interval of 5% to event firms. However, only equally-weighted portfolios have been taken into account. Table 3 reveals that test statistics based on the standardized calendar time approach are more powerful than those based on traditional methods. For instance, with 15% per year abnormal returns, the rejection rates are 92% for SCTA, 79% for BHAR method and 75% for MMCTAR approach.

It is noteworthy that a well-specified test statistic is useless if it does not have power to correctly detect the signal of an abnormal return. Alternatively, instead of ability to detect the alternative hypothesis when it is true, power is the probability that a test correctly rejects the null hypothesis when it is false. Without power, statistical tests are useless in making inferences about a statistical population. Thus, we strongly recommend the application of standardized calendar time approach in the analysis of long-term stock returns after corporate events.

Table 2. Specification of tests in random samples

| Methods | Benchmark | 1 year | | 3 years | | 5 years | |
|---|---|---|---|---|---|---|---|
| | | 2.5 | 97.5 | 2.5 | 97.5 | 2.5 | 97.5 |
| Standardized calendar time approach (SCTA) | Size-BM control firm | 2.1 | 1.7 | 1.4 | 2.0 | 3.0 | 1.1 |
| Buy-and-hold abnormal return method (BHAR) | Size-BM control firm | 5.2* | 0.2 | 3.9* | 0.8 | 3.8* | 1.2 |
| Mean monthly calendar time abnormal returns (MMCTAR) | Size-BM control firm | 3.9* | 1.6 | 3.2 | 2.8 | 2.3 | 2.6 |

Note: This table presents the percentages of 1000 random samples of 200 firms that reject the null hypothesis of no annual, three-year and five-year abnormal returns at 5% level of significance. The numbers marked with * suggest that the empirical size is significantly different from the 5% significance level.

Table 3. Power of alternative methods in Random samples

| Methods | Induced level of abnormal return (%) over 3 years | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | -20 | -15 | -10 | -5 | 0 | 5 | 10 | 15 | 20 |
| Standardized calendar time approach (SCTA) | 0.94 | 0.76 | 0.60 | 0.18 | 0.05 | 0.31 | 0.74 | 0.92 | 1.00 |
| Buy-and-hold abnormal return method (BHAR) | 0.87 | 0.70 | 0.55 | 0.16 | 0.05 | 0.26 | 0.63 | 0.79 | 0.96 |
| Mean monthly calendar time abnormal returns (MMCTAR) | 0.84 | 0.62 | 0.43 | 0.12 | 0.03 | 0.23 | 0.53 | 0.75 | 0.89 |

Note: This table presents the percentages of 1000 random samples of 200 firms that reject the null hypothesis of no abnormal returns over a three-year holding period. We add the levels of annual abnormal return indicated in the column heading. The observations shown in this table argue that SCTA has higher power than the rest.

## Conclusions

While short-run event studies are relatively stable and free of limitations, the interpretation of long-run results is still problematic. The prime objective of the present paper is to discuss the major limitations of the existing methodologies employed for investigating long-term performance of firms experiencing certain corporate events. In order to serve this purpose, we review a number of long-run event study papers. In addition, we give an empirical example to compare the performance of the popular measures of long-horizon abnormal stock returns. Our investigation documents that although long-run event studies have advanced over the years, the power and specification issues still remain unsolved and further filtering of the existing methods is thus required for resolving these issues.

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